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# R&D ADVANCES IN USAF PILOT TRAINING

ARMSTRONG LABORATORY


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The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

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Recent advances in aircrew training methods and technologies now allow the Air Force to conceptualize training as the peacetime manifestation of war. That is, ground-based pilot training can now move beyond simply training procedural skills to training wartime mission skills on a much more frequent basis than past training range has allowed. We discuss R&D advances in three key areas that will truly allow the US Air Force to train as it intends to fight. These three areas are "Warfighter Training Behavioral Research," "Distributed Mission Training Engineering Development," and "Night Vision Device Training R&D." Under each of these three main categories of R&D, we discuss specific advances made at the Armstrong Laboratory, Human Resources Directorate, Aircrew Training Research Division. We also discuss future directions that we believe aircrew R&D should advance in order to provide synthetic training environments that will allow the full measure of warfighting skills to be trained.

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## PREFACE

This report gives a broadbrush view of a variety of research and development (R&D) activities being undertaken at the Armstrong Laboratory's Aircrew Training Research Division (AL/HRA) which is located at the Williams Gateway Airport in Mesa, Arizona. This effort is being reported under Work Unit 1123-B2-14, Simulation and Modeling Technology Support. Col Lynn A. Carroll, AL/HRA Division Chief, was the laboratory technical monitor. This report documents a presentation made to the 81st Panel Meeting/Symposium of the Advisory Group for Aerospace Research & Development (AGARD), Aerospace Medical Panel on Selection and Training Advances in Aviation, which was held 27-31 May 1996 in Prague, Czech Republic.

# R&D ADVANCES IN USAF PILOT TRAINING

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**SUMMARY**

Recent advances in aircrew training methods and technologies now allow the Air Force to conceptualize training as the peacetime manifestation of war. That is, ground-based pilot training can now move beyond simply training procedural skills to training wartime mission skills on a much more frequent basis than past training range training has allowed. We discuss R&D advances in three key areas that will truly allow the Air Force to train as it intends to fight. These three areas are "Warfighter Training Behavioral Research", "Distributed Mission Training Engineering Development", and "Night Vision Device Training R&D". Under each of these three main categories of R&D we discuss specific advances made in our laboratory. We also discuss future directions that we believe aircrew R&D should advance in order to provide synthetic training environments that will allow the full measure of warfighting skills to be trained.

## I INTRODUCTION

The US Air Force's Major Commands are committed to an aggressive process of continual improvement in their aircrew training programs. More complex training requirements are continually evolving at the same time that training resources are becoming scarce. This combination of doing more with less has heightened Air Force interest in discovering and effectively using innovative training techniques and technologies.

For example, a "Four Star Summit" on modeling and simulation was held by the Air Force Chief of Staff, Gen. Ronald Fogleman, in June of 1995. The effective use of modeling and simulation for all types of training and mission rehearsal was a major topic of discussion at the Summit. The recently developed capability to link a variety of training simulators, constructive models, and live aircraft in a wide area network to accomplish mission training was endorsed by the Air Force leadership. In addition, the Air Force Scientific Advisory Board has pointed out the utility of using modeling and simulation to increase the scope and realism of warfighter training at an affordable cost.

As powerful as these new modeling and simulation tools can be, they can only be effectively used if all aspects of quality training system development are understood. The Armstrong Laboratory's Aircrew Training Research Division (AL/HRA) has a robust training R&D program which is described in this paper. The program is aimed at producing a solid research foundation upon which sound training system development principles can be based. Modeling and simulation are a major part of AL/HRA's "toolkit", but it's AL/HRA's skilled scientists, engineers, computer scientists, and pilots who bring the true training systems perspective to all of the R&D that we produce.

The work at AL/HRA is concentrated into three main areas:

- Training the Warfighter behavioral research
- Distributed Mission Training Engineering Development
- Night Vision Device Aircrew Training Behavioral Research and Engineering Development

This paper describes all three areas, and shows the interaction between them. Our work in these areas is integrated and not mutually exclusive. Major R&D innovations at our Division are described along with significant R&D efforts we see on the horizon. We have decided in this paper to give a broadbrush view of a variety of R&D activities, rather than give detailed descriptions of just a few R&D topics. Please contact or visit us if you would like more information on any of these activities.

## II. TRAINING THE WARFIGHTER BEHAVIORAL RESEARCH

### Training Guidelines for Multiship Simulation Training

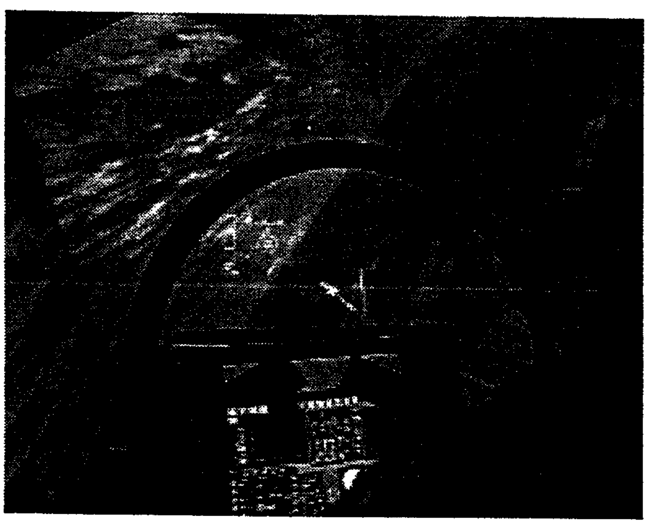
Recent advances in simulator networking have allowed the construction of large confederations of disparate simulators. A variety of aircraft simulators can now be linked, and in the future, as simulator costs continue to drop, we expect to see literally hundreds of training devices from the Air Force, other US military services and allied countries conduct joint training together. The effectiveness of such training will largely depend on the quality of training guidelines that can be given to those who conduct such training. Experience thus far has shown that merely using the same training techniques in networked simulators for training combat skills as are used on training ranges is inefficient and does not take full advantage of the simulators unique advantages. The simulated combat environment provides special instructional advantages that are not found on ranges, which have a variety of training constraints. For example, flight training does not allow real-time kill removal during an engagement, which can significantly change the outcome of the training engagement. Range training restricts the electronic warfare aspect of the battle due to security constraints. Simulator training allows for a complete range of electronic warfare tactics and equipment to be conducted. Briefing as teams can be more efficiently performed in simulated environments than with range training, especially when geographically dispersed units are involved.

AL/HRA's work with multiship training is aimed at developing training guidelines that will allow instructors and trainees to take maximum advantage of synthetic environments. We are producing guidelines based upon empirical data and empirical experience garnered through a variety of studies in our multiship simulators. We are interested in helping major user commands de-

velop multiship training strategies. These strategies define; who should be trained, what skills and knowledge should be trained, where and when the training should take place, and how the training should be evaluated. Our multiship studies examine novel training interventions that are allowed for the first time by synthetic environments. We also attempt to determine whether existing training technologies will be sufficient to allow multiship combat skills to be trained, and if not what new technologies should be developed.

### Combat Situational Awareness Research

At present, there is considerable interest in situational awareness (SA). Loss of SA is considered to be a major factor in many aviation accidents. From an operational standpoint, there is also interest in SA as an important element that largely determines success within a tactical aviation environment. Against this backdrop of general interest in SA across a variety of domains, the Armstrong Laboratory recently completed a large-scale investigation of SA within the operational fighter community in response to a request from the Air Force Chief of Staff. Questions posed by the Chief included: What is it? Can we measure it? Is it learned or does it represent some type of basic ability or characteristic that some have and others don't? From a research standpoint, these questions translated into issues of measurement, selection, and training, which the laboratory has been researching for some years.



MULTIRAD Environment

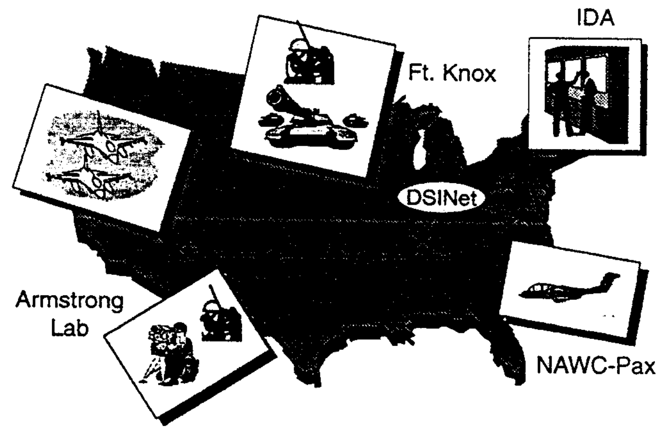
AL/HRA was responsible for two main thrusts in the larger Armstrong Laboratory effort: the development of measures and the study of the role of training in developing SA. In particular, a number of assessment tools, based on a combination of supervisor, peer, and self-report judgments, were successfully developed for measuring SA in operational fighter squadrons. Additionally, a series of SA simulation scenarios were developed for the Division's Multiship R&D simulation facility described elsewhere in this paper. Of those individuals evaluated in the operational squadrons, a sample of 40 pilots were evaluated using the specially developed scenarios that are representative of a high fidelity F-15 combat mission environment. The results point to the salience of training rather than selection as the prime way of enhancing SA in the combat environment. Moreover, the data suggest that multiship simulation training can be an important tool in developing and maintaining SA within our operational forces. Current efforts are focused on an in-depth analysis of data that were gathered in the simulation portion of the study.

An attempt is being made to identify those individual characteristics that distinguish those pilots who performed extremely well versus those who performed poorly in the simulated combat environment. If such characteristics can be reliably measured, it becomes possible to design training programs that target the development of those skills that lead to expert performance. An additional finding of the study was the potential value of eye-movement recordings as a training tool. An effort is currently underway to explore the benefit of these recordings as a tool for providing real-time feedback as well as post-mission debriefing.

### Joint and Multi-Service Distributed Training Research

The joint and Multi-Service Distributed Training Testbed (JMDT2) is a multi-service research and development program.

The JMDT2 provides the services a common training effectiveness testbed. Participants use this testbed to investigate multi-service training strategies and methods. The testbed provides a continuing means to investigate multi-service training effectiveness issues. These training effectiveness issues include the role of instructors in distributed interactive simulations, multi-service versus individual service training feedback, and methods of maximizing training value for each individual participant.




Multiservice distributed training testbed for close air support.

The testbed includes a network of geographically distributed simulators. These simulators communicate with each other over a wide area network using Distributed Interactive Simulation communication protocols. This network includes armor simulators at Ft. Knox as well as aircraft simulators at the Naval Air Warfare Center and at Armstrong laboratory.

Initial research has focused on training the execution of close air support. Close air support was selected because it requires the synchronization of both command and control and tactical elements between the services. Plans are currently being formulated to extend the JMDT2 testbed to address training research issues involving air-to-air combat and joint fire support. Data

collected to date indicates that JMDT2 provides effective training for a variety of combat tasks.

Armstrong Laboratory is contributing to both the training and engineering aspects of this program. Training researchers from AL/HRA in cooperation with researchers from the other services are identifying training objectives, developing performance measures, and designing training scenarios. AL/HRA personnel are responsible for network integration and communication. In addition, AL/HRA simulation technologies involving aircrew training devices, visual displays, computer image generators, and long-haul secure networking are among the enabling technologies needed to establish the testbed.

**Special Operations Forces Training and Mission Rehearsal Research**

The Air Force Special Operations community has embarked on several major modernization programs to enhance training and provide simulation-based mission rehearsal capabilities for the crew members of all special operations weapon systems. The first element to be delivered was the MH-53J Weapon System Trainer (WST)/Mission Rehearsal System, which was accepted by the 58th Operations Group (58 OG) at Kirtland AFB NM in 1990. The 58 OG training and rehearsal system has since been expanded to include TH-53A and MH-60G helicopter simulators, an electronic combat environment simulator, and a training observation center that allows training in any of the simulators to be monitored at a centralized facility.

The 58 OG and AL/HRA have formed a research partnership to address such issues, how new simulation innovations impact the mission preparation process and ultimately, the ability to accomplish the mission. A highly related issue is how to structure the mission preparation process in a way that uses these rehearsal capabilities to best advantage.

AL/HRA and 58 OG recently completed an initial assessment of MH-53J Mission Rehearsal System effectiveness. Crew reaction to this simulation-based rehearsal capability were uniformly positive. Most pilots reported that rehearsal in the simulator resulted in a better understanding of the mission plan and an increased probability of mission success.

A scene generated by the MH-53J Weapon System Trainer/Mission Rehearsal System.

AL/HRA is currently developing utilization strategies using the multi-ship, interactive environment for rotary-wing airframes at the 58 OG. AL/HRA sponsored the creation of a model that depicts the mission preparation activities performed by Combat Talon I (MC-130E) aircrews. The basic flow of events was depicted along with information gathered and used, decisions made throughout the process, mission planning tools used, products generated, and quality metrics used to assess the plan.

This model has been expanded to incorporate MH-53J mission preparation, leading to a general mission preparation model for any Air Force Special Operations air frame. The model addresses both single-ship and multi-ship missions. We also developed a human activity system model of simulation-based rehearsal that identifies (1) many functions throughout mission preparation where modeling and simulation can improve the process, (2) the essential elements of simulation-based rehearsal including the varied people who must be involved, and (3) processes to harness the power of simulation in support of mission preparation.

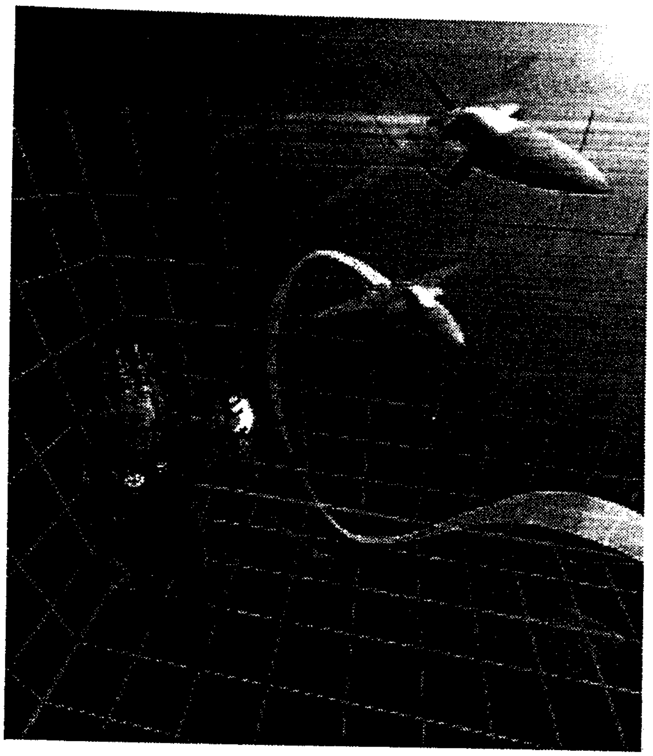
We are beginning to investigate simulation-based combat mission training issues in conjunction with the 58th OG, focusing on crew coordination and team training. This research will initially address HC-130P training, but will be expanded to incorporate rotary-wing training and multi-ship (rotary-wing and fixed-wing) training. Specific objectives are: (1) identify, develop, and validate measures of crew and team performance that can be used either in simulators or in flight; and (2) provide a framework for generating information from training and rehearsal performance that can be used to accurately assess the operational readiness of crews and teams for complex joint-service missions. The addition of the aerial gunner/scanner simulator to the training capabilities at the 58th OG in 1996 will provide an opportunity to ascertain how modeling and simulation for the entire flight crew impacts subsequent performance in training flights and in subsequent operational assignments.

**Virtual Environment Visualization Training Research**

Spatial awareness, the ability to apprehend the spatial parameters of an air-combat situation presents a difficult learning problem because the operator must mentally visualize a three-dimensional (3-D) environment by reading and interpreting 2-D displays. However, the technology is now available to supply trainees with a more realistic, 3-D view of the situation as it unfolds in time. This technology, variously called "virtual reality" or "virtual environment," is capable of giving Air Force trainees the ability to experience firsthand the spatial situation of the air combat arena in a computer-generated virtual world.

The promise of virtual environment technologies is that the once rigid boundary separating mind and machine can be blurred. The user is free to interact intuitively with objects and events in a 3-D world which exists solely to support task demands. Through this interaction, the user may experience psychological immersion, or 'presence' in the synthetic world, thereby heightening the vividness and impact of the training encounter. The virtual environment visualization training systems being designed at Armstrong Laboratory capitalize on these attributes to aid student pilots and ground control operators to visualize, understand, and implement air-to-air intercepts. Three virtual environment training systems are available for spatial awareness training: a head-up display (HUD)/radar symbology training, a debrief interface, and a ground control station.

The Spatial Cognition Multi-media Trainer is designed to augment academic instruction with an interactive tool which allows the trainee to practice visualization skills under conditions that mimic the in-flight spatial problem-solving situation. Within the virtual environment, the student views HUD information specifying the target's location and stereoscopic model representing the target. Using a six-degree-of-freedom input device, the student positions the model plane to match the HUD. The system provides feedback in the form of a second model which accurately represents the HUD information. To enhance the realism of this virtual environment display, the out-of-window view of the fighter's airspace accurately maps the target's location in virtual airspace visually and kinesthetically into the room in which the system is housed. Correspondence between real and virtual worlds, coupled with head-tracked imagery and wide field of view capitalizes on the psychological immersion of virtual-world technologies.



A virtual environment station.

The Virtual Environment Debrief interface was developed to be used in conjunction with Armstrong Laboratory's F-16 Air Intercept Trainer (AIT), a part-task trainer which offers concentrated practice using Hands-On Throttle and Stick (HOTAS) to accomplish radar air intercept training. Throughout the simulated sortie, the AIT records mission performance by time sampling the spatial locations of all combatants and mission-critical event information. The data are ported to a low-cost, commercially available, microcomputer for projection into a stereoscopic helmet-mounted display. The virtual world in this display maps a 40-mile square airspace to the real world coordinates of a room measuring 10' x 10' x 8' (H). The three-dimensional spatial coordinates of the aircraft (ownship and up to 5 targets) as they unfold during the scenario are projected into this world. Critical intercept events (e.g., radar mode) are displayed at the time and place of their occurrence.

To increase opportunities for gaining insight from the virtualized intercept, the debrief system also provides an interactive human/computer interface which enables the user to actively explore the data set—assuming a new viewing angle, zooming, panning and so forth. Using a commercially-available head-tracking system, the pilot may move anywhere within the three-dimensional world and assume any orientation relative to that world. This allows the pilot to examine, in detail, points along the trajectory at which critical changes in the spatial relationships of the ownship and target occurred. The real-time image generation system is designed to project imagery appropriate to the gaze direction as interpreted by the head-tracking system. Any user familiar with computers, simulators, or video arcade games can readily adapt to using the virtual environment debrief interface.

The Ground Control Intercept (GCI) operator confronts a spatial awareness problem very similar to that encountered by the fighter pilot—creating a mental model of a 3-D situation by reading and interpreting a 2-D display. The Virtual Environment Ground Command/Control System was developed for training GCI operators to support fighter aircrews through the acquisition and maintenance of spatial awareness over the vast expanse of airspace observed by ground-based and airborne radar systems.

When coupled with Armstrong Laboratory's Mission Support System (MSS), the ground control interface is capable of interacting with a variety of simulators as well as the Distributed Interactive Simulation (DIS) Network for real-time ground communications during a simulated wargame. The data are ported to a Silicon Graphics Crimson™ workstation for generation of stereoscopic imagery in a high resolution helmet-mounted display. In accord with the operating constraints of existing GCI systems, the spatial locations of all combatants and mission-critical event information are time sampled and updated at the rate of a single radar scan. For unconstrained realism in the virtual environment, the data also may be updated to 30Hz.

The virtual world of ground communications is austere, consisting of a simple wireframe terrain spanning a hundred miles in each direction. To facilitate surveillance of the airspace, the Ground Command/Control System allows the operator to actively explore the data set under two interactive modes. First, using the helmet-mounted head-tracking system, the operator may scrutinize a dogfight at close range and from a variety of viewpoints. For global surveillance, the operator may fly through the vast three-dimensional world by using a hand-held six-degree-of-freedom input device. Simple color-coded icons represent friendly and hostile aircraft. The icons' movements in the virtual world correspond to the real-time movements of the simulated aircraft. To monitor the activities of a single hostile relative to the friendly fighter, the operator may 'hook' a target icon. Upon acquiring a hook, a vector connects the two aircraft and indicates the target's relative position and heading. A pull-down menu provides additional information about each friendly and hostile aircraft and is displayed on a 2-D screen that moves with the observer.

### Visual Training Research

The role of visual system technology is critical in providing fully immersive fighting environments. Advances in visual simulation technology have been made in image generation, display,

and database systems. However, many of these advances have not been tested in an operational environment and it is not yet clear that they will fully support current and future simulation training requirements. The goals of the visual training research program are to define the functional requirements for visual systems and to define the relationship between visual system capability and training value. Previous research concentrated on five areas:

(1) scene content for low altitude flight,

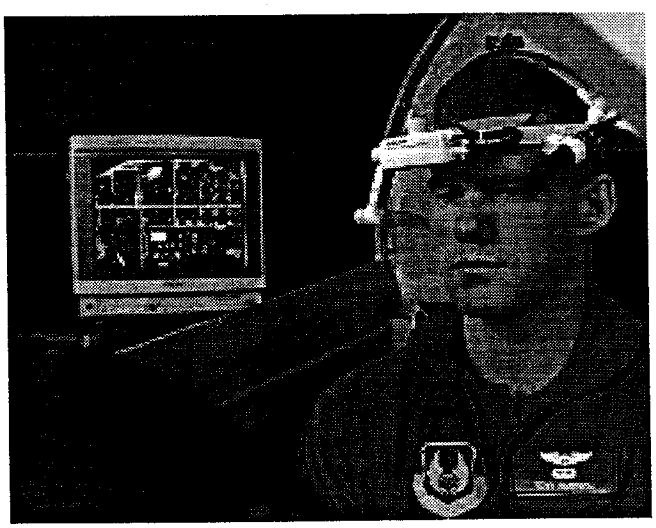
(2) color perception control,

(3) field of view requirements,

(4) spatial and temporal perception,

(5 trade-offs between display brightness, contrast and resolution.

This research resulted in specific recommendations for display design, image generation requirements, and database capabilities. Findings specify the level of terrain resolution required for low altitude flight, the level of object density and realism required, the effects of image generation update rate on object recognition and motion perception, the relationship between ground texture characteristics and altitude and velocity perception, a software control procedure for device independent color matching and achieving naturalistic (i.e., "real world") appearing colors, and the effects of display characteristics on the occurrence of simulator side effects such a eye strain and headaches. In addition, a comprehensive annotated bibliography of visual display-related research was published during the last year which can be used by the research and engineering communities as a reference document.



**Eye Tracker**

Current research is focused on:

(1) defining the requirements for dissimilar networked visual systems used in distributed mission training,

(2) object size and distance and motion perception as it relates to display viewing distance and level of scene detail,

(3) naturalistic color perception in mesopic displays,

(4) the effects of stereoscopic display disparities on spatial perception, especially as related to surface slant and inclination, and

(5) the use of an eye-tracking device as a training aid.

A laboratory research program has been initiated that will lead to the development of functional performance specifications for use in simulator visual displays ranging in application from individualized training to large-force joint exercises. To support this research program, AL/HRA has dedicated a visual display and imagery laboratory which includes rear projection screens, single and multiple light valve projectors, SGI graphic workstations, and access to modern image generation systems. We have also developed an eye-tracking laboratory which includes several eye-tracking devices, software to conduct on-line and off-line analyses of eye movements, and a portable head-mounted eye position monitoring and recording system. In addition, AL/HRA facilities include fiber optic head-mounted displays, two full field-of-view visual displays, and a variety of fighter aircraft cockpit capabilities.

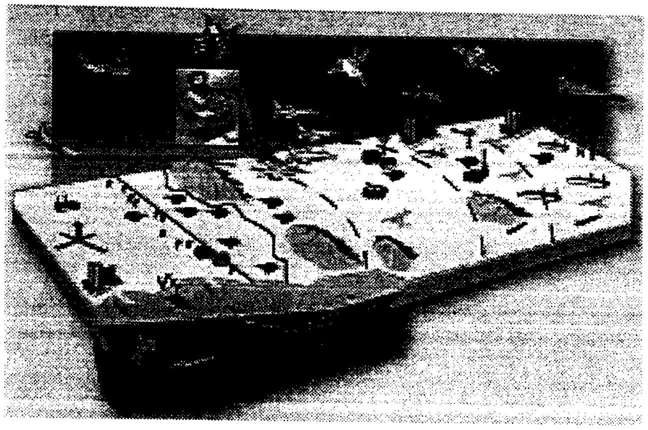
## III. DISTRIBUTED MISSION TRAINING (DMT) ENGINEERING DEVELOPMENT

In the past, aircrew training has been heavily dependent on actual aircraft as the only realistic media for providing mission training. Aircraft training devices were used predominantly to better prepare the aircrew to more effectively use limited flying hours. However, increasing training requirements coupled with expanding peacetime constraints have reduced both the quality and quantity of realistic, available training for our aircrews. Now, with the dramatic improvements in the capability and affordability of advanced distributed simulation (ADS) technologies, aircrew training can be significantly improved using the concept of distributed mission training.

Distributed training allows multiple players at multiple sites to engage in training scenarios ranging from individual and team participation up to full theater level battles. It allows participation using nearly any type of networkable training device or the actual weapon system. Additionally, computer generated or constructive forces can be used to substantially robust the scenario. This combination of live, virtual and constructive environments will allow nearly unlimited training opportunities for service, joint and combined forces from their own location or a deployed training site. This expanding capability will provide on-demand, realistic training opportunities for all aircrews in the future by overcoming many of the current constraints that limit training effectiveness and arbitrarily cap readiness levels. Distributed mission training will dramatically improve the quality and quantity of aircrew training and will provide the most significant increase in readiness since the inception of RED FLAG and the AGGRESSOR programs in the 1970s.

Aircrews in low cost, high fidelity unit level simulators with full visual systems will be immersed in the training arena or the joint synthetic battlespace. There they will network and team with other air, ground, sea, and space forces to execute the air tasking order in a specific training scenario developed and managed by respective battlestaffs. At other times, units will conduct local training or workups for major exercises using the system. However, to make this a reality, many of the enabling technologies must be significantly improved and made affordable. While low-

cost cockpits are available, these devices must now become surrogate weapon systems rather than superficial emulations that merely complement the aircraft. Visual and cuing systems must adequately represent the environment to allow the players to execute their missions. The thumbnail criteria of 20/20 visual acuity represents a significant leap in technology and affordability. Networking requirements include local, long-haul and multilevel security challenges to reliably connect disparate sites around the world. Network interface units and Distributed Interactive Simulation (DIS) protocols must be expanded to accommodate massive amounts of information and traffic generated by thousands of entities. Mission control stations, threat systems and mission support stations must be universalized and standardized to provide mission planning, coordination and execution capabilities to the warfighters. Brief and debrief capabilities must be part of the system to maximize training and to address safety issues.



Joint Synthetic Battlespace

The laboratory is supporting the development, demonstration, evaluation, and transition of those enabling technologies needed for effective, affordable distributed mission training for the aircrews. Those efforts capitalize on the Multiship Research and Development program and other numerous initiatives designed to improve capability and affordability of ground-based training.

**DMT Cockpit Simulation Technologies**

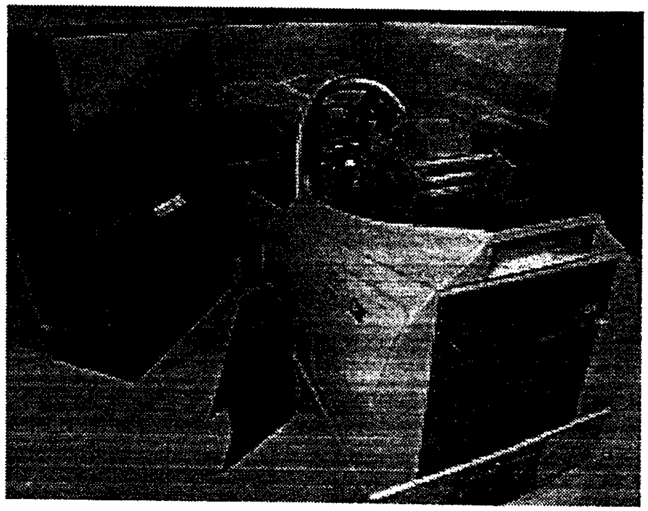
The Multi-task Trainer(MTT)/Unit Level Training (ULT) program was initiated specifically to address unit-level training. The unit environment requires reducing the life cycle costs, space, power, and maintenance requirements while providing experienced pilots equivalent fidelity and systems concurrency with their aircraft. A simulator at the squadron must provide individual stand-alone training , instructor-initiated training, and tactics, team and mission training — all from the same device and control console. The MTT has provided high fidelity and concurrency via the use of converted aircraft operational flight programs (OFPs); team training via local and long-haul networking; sensor and weapons training via correlated sensor systems; and deployment support to forward operating locations via its self-contained design, which then provides the cornerstone of mission training and future developments.

The MTT/ULT cockpit is functionally equivalent to its respective aircraft. The full fidelity instrumentation and controls are essential for a complete range of emergency procedures (EP) training. A single MTT/ULT has capabilities to train operational aircrews in a variety of skills. Networked with other MTT/ULTs, training impact can be multiplied for team training exercises and tactics.

Such features make the MTT/ULT design eminently suitable for use in operational squadrons. Efficiency and reliability were very high during in-squadron testing of the F-16 MTT. Operating on three 20-amp, 110-volt power outlets in a standard office environment, the F-16 MTT requires no external support. It can be quickly dismantled and can pass through a 36" doorway for ease of transport. The F-16 MTT fits virtually any squadron setting and could probably accompany a unit to the combat zone. The MTT requires three 20-amp, 110 volt power outlets in a standard office environment. It can be quickly dismantled and can pass through a 36" doorway for ease of transport. The F-16 MTT fits virtually any squadron setting and could probably accompany a unit to the combat zone.

In October 1993, the F-16 MTT went through extensive testing over a three-week period, and reached a major milestone of becoming the first deployable training device to be simulator certified. Certification attests to the high fidelity and reliability of the MTT software and hardware.

To shortcut software development, the F-16 MTT/ULT uses existing Air Force-owned operational flight trainer (OFT) computer code along with aircraft OFP software from the aircraft systems' line replaceable units (LRU). Aircraft software was used to ensure a direct and maintainable correspondence of the trainer to the aircraft (concurrency). OFT and LRU software was converted to run at the 50Hz rate of the aircraft microprocessors. Use of government-owned software kept development risk and cost low while maintaining the highest level of simulation fidelity. It also ensured MTT/ULT concurrency with the aircraft as evidenced by recertification of the F-16 MTT with the SCU-2 avionics upgrade ahead of the aircraft.



Recycled A-10 OFT using MTT architecture with SE2000 visual.

As investment technology, the MTT/ULT program sets a new standard for cost-to-capability of simulators and allows for easy

expansion for other aircraft. MTT/ULT projects target training requirements and exploit modern technology to achieve fidelity and concurrency. A-10 OFTs have been quickly recycled using MTT architecture, while AL/HRA is on line to convert the A-10 LASTE software. The A-10 MTT was used to prototype other space-saving and increased fidelity technologies such as new digital control loading devices which are also targeted for use in the C-130 ULT. The C-130H3 ULT will revolutionize training availability and quality for the wide body aircraft community. Existing simulators use motion-based platform systems that are expensive to procure and maintain and require specialized facilities and maintainers. A wide body, unit-level trainer will require an MTT-based high fidelity cockpit, the latest in graphical user interface (GUI) operator consoles, and modern technology for providing necessary cuing so that it will fit in existing squadron facilities. Although not quite as mobile as the F-16 MTT, the C-130 ULT has still been designed for modular assembly with quick disconnect points for rapid deployment to any needed location. The F-16 MTT occupies a floor area of only 5' x 6', while the C-130 dimensions are 14'L x 10'W x 12'H. Instead of treating F-16, A-10 and C-130 simulators as three separate and distinct training systems, Armstrong Laboratory, through its quality approach to training, has been able to standardize hardware components through the use of open VME architecture. This approach is inexpensive and simple, yet flexible and elegant for self-contained simulators and will greatly reduce the logistics required by users to support numerous unit-level, high-fidelity training systems. All MTTs and ULTs are designed with inherent local and long-haul networking capabilities to enable the devices to be used in joint service DIS exercises promoting greater interoperability among services.

With the F-16, A-10, and C-130 MTT/ULT, AL/HRA is continually demonstrating how advanced technology can make state-of-the-art simulation affordable and available to aircrews. The size and cost of the conventional F-16 simulator (OFT) has been reduced by a factor of 10, and the C-130 ULT will be higher fidelity than the WST at approximately one-third the cost. Fidelity combined with the compactness of a unit trainer that is self-contained with all computational systems, input/output linkages, control loaders, cooling and operator console, and modest power requirements make the MTT mobile, flexible, and affordable.

Our Division has also demonstrated the efficacy of "recycling" old, expensive simulators using the new architecture and rehosted software at a tremendous savings.

**Visual System Technologies**

An "inexpensive" answer to tactical simulation.

In order to effectively prepare for combat, a training device needs to allow the aircrew to employ the weapon system as they would in an actual conflict. The objective of this program is to develop and demonstrate a significantly more cost-effective display capability with the flexibility to address a variety of weapon system simulation requirements.

The DART series of displays are located in the TEMPEST facility of AL/HRA, at Williams Gateway Airport in Mesa, AZ. These displays capitalize on the trend that image generators (IG) will soon be inexpensive enough to make it cost effective to wrap many channels of imagery around a cockpit. This display approach explores the arena of low-cost display devices which achieve sufficient fidelity to provide a useful training tool.

The original DART system is configured as a rear screen projected dodecahedron with nine channels of imagery surrounding the design eyepoint. The screens used are flat, have a net gain of one, and are abutted with gaps of approximately a centimeter. The projectors are off-the-shelf, CRT-based, 2000-line systems. The result is wraparound real imagery, presented about 37 inches away, with luminance levels of 10 footLamberts at the edge of a screen, rising to 25 footLamberts at the center. The resolution is 4.25 arc minutes/pixel and the field of regard 360 degrees horizontally by 260 degrees vertically. With eight channels on, the contrast ratio has been measured at 50:1. A Polhemus head-tracker is used to determine where imagery is not required so that six IG channels can be channel switched to cover the nine available projectors. Six channels are sufficient to present the perception of projectors blinking on and off in the pilot's peripheral vision. A rear-screen mounted monochrome green projector provides an effective representation of an F-16C or F-15C head-up display.

Typical imagery in front half of Mini-DART.

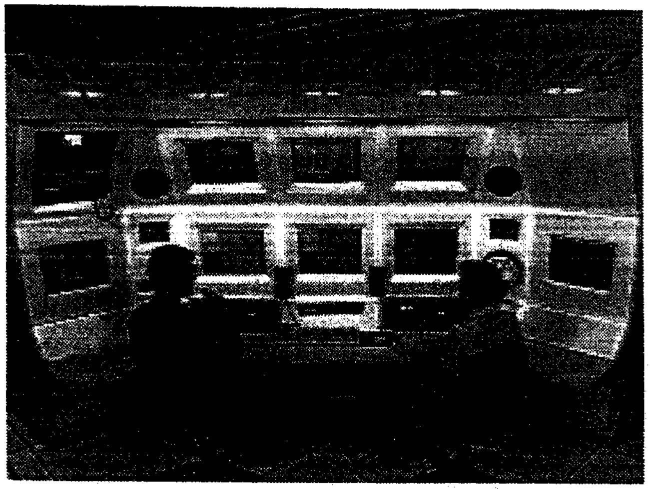
The Mini-Dart deviates from the original DART approach having been constructed of rectangular and trapezoidal screens with a 24-inch screen viewing distance which is significantly closed than the 37-inch screen viewing distance demonstrated with the DART. This design is more compact making it capable of fitting within a 10-foot ceiling height and it requires only four image generator channels to cover its eight wrap-around screens. Finally, the four-screen deployable DART is similar to the front half of the Mini-DART with each side screen wrapped 30 degrees past half way around.

Future refinements to the DART concept will include the development of a helmet-mounted, area-of-interest capability to provide the high resolution for the current DART system, and alternative higher resolution projectors employing background rasters, mini-rasters and calligraphic imagery in order to increase the display resolution while reducing system complexity and cost. As part of this effort, an interface standard is being explored which will allow the government to employ current valuable image generation capabilities aggregated with evolving high resolution target imagery for graduated increases in display fidelity.

**Training System Control Technologies**

The Multiship Support System (MSS) supports multiship training research by providing mission planning, initialization and control, performance monitoring and measurement, data collection, debrief, and operator voice communication control for networked simulation devices. MSS communicates using Distributed Interactive Simulation (DIS) standard protocol data units. With the exception of the video tape recordings made for debrief, it is transparent to the MSS whether a simulator is on the local network or connected over a wide-area network.

The Multiship Support System consists of a real-time support station, a mission planning station, two debrief stations, and a large-scale display facility.



Simulation Management Station (SiMan)

The Simulation Management (SiMan) station is the nerve center of the MSS. It provides the scenario planning, initialization and control, performance monitoring and measurement, and data collection functions of the MSS. Along with the mission planning station, the real-time support station provides pre-mission setup and initialization as well as the real-time control for the operator/researcher. Displays in the real-time support station show a repeat of the out-the-window view from two selected flight simulators, the instrument displays from two flight simulators, a repeat of the ground control intercept (GCI) or airborne warning and control system (AWACS) simulators display, an operator display from which the exercise can be set up and controlled, a "God's-eye view" and perspective view display for initializing and monitoring the exercise, and a researcher display. A summary of the exercise can be selected at the researcher display alternating with a display designed and created by the researcher. As soon as an exercise is completed, the summary display is printed and within minutes the data and video tapes are moved to the debrief station for the debrief to begin.

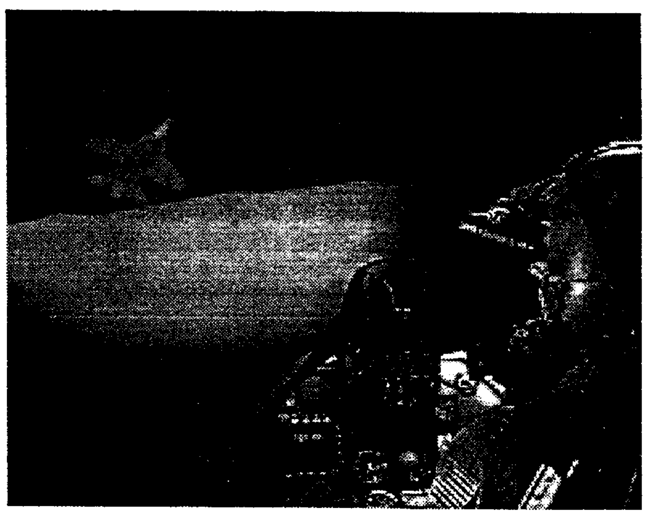
The mission planning station provides a way to input mission planning data in a manner similar to the method used for the actual aircraft. The data are written to floppy disks and moved to the SiMan station for forwarding to the flight simulators as part of the initialization procedure. Mission planning is done on a personal computer system that is derived form the mission planning system used in operational F-16 units. The software has been modified to support mission planning for other types of aircraft in addition to the F-16.

The debrief stations provide post-mission support. The displays consist of video playback of two selected cockpit displays and of the AWACS station, graphically generated out-the-window displays for any two entities on the network, and a controllable God's-eye/perspective view of the exercise. The students may use the perspective display to watch the exercise from different points of view, providing a better picture.

## IV. NIGHT VISION DEVICE TRAINING R&D

The capability afforded by night vision devices (NVD) for the conduct of nighttime military operations has literally revolutionized modern warfare. Certainly, the recent war in the Persian Gulf was a convincing demonstration of an overwhelming military advantage due in large part to night vision technology. NVDs, primarily night vision goggles (NVG) and forward-looking infrared (FLIR) sensors have become an integral part of night operations for many aircraft, both rotary and fixed-wing. While NVDs impart a significantly increased capability over unaided night vision, their restricted field of view and reduced resolution (visual acuity) are somewhat deficient when compared to unaided day vision. In addition, the imagery produced by NVDs has unique characteristics that require specific interpretive techniques which must be learned by the operator. These aspects of night vision technology have a significant impact on operational procedures and training requirements.

It is a certainty that nighttime military operations will receive even more emphasis in the future, but training at night will be constrained by shrinking resources, airspace restrictions, and reduced manning. Cost-effective, ground-based training systems and facilities will be essential.



NVG-Compatible Simulator

The Night Vision Program of the Aircrew Training Research Division, was established to meet the operational training requirements of both existing and future systems. After thorough review of existing DoD NVD aircrew training programs, research objectives were developed with user inputs and contributions by subject-matter experts. The first completed product was the NVG Test Lane, which combines a specially designed NVG resolu-

tion chart (developed at AL/CFHV) and standardized light source with a comprehensive set of adjustment and assessment procedures. The NVG Test Lane provides, for the first time, a practical means by which NVGs can be adequately adjusted and functionally assessed in an operational setting. This capability is vital not only for initial NVG training, but also for routine pre-flight procedures in operational units.

A Basic Instructor Course for NVG ground training has also been produced on videodisc and is now in use by all Air Force major commands. Individual modules include:

- Visual Physiology and Spatial Orientation,
- Fatigue and Circadian Rhythm,
- The Night Environment and NVD Theory,
- NVG Adjustment and Pre-flight Assessment Procedures, and
- Cockpit Procedures.

Applied visual research is under way to enhance our understanding of aided night vision. This includes the investigation of size and distance perception with NVGs, the role of unaided peripheral vision on aircrew performance during NVG-aided flight, and the effects of degraded images on perception and performance.

Future research will include the development and evaluation of a low-cost, portable night vision training system which will enable mission training and rehearsal at remote sites as well as at home base.

The objective of the NVD training research program is to produce cost-effective, comprehensive ground-based training that prepares aircrew members for the unique aspects of NVD employment and enhances Air Force operational capabilities and safety in night operations.

## V. CONCLUSION

The U.S. Air Force has embarked on an initiative to revolutionize training through expanded use and application of the technologies just discussed. The result may be merely modernization of existing training programs, or more likely to total change in our training philosophy from one that predominately relies on the weapon system to one that merely uses the weapon system to validate training, to provide acclimation in the actual environment or to enhance long-term experience. All the rest will be accomplished in simulated surrogate weapon systems that are networked with the rest of the combat participants, friends or foes. In either scenario, considerable research and development will be required to produce the needed capabilities and to validate the effects.